US009097555B2

(12) **United States Patent**
Trevino et al.

(10) **Patent No.: US 9,097,555 B2**
(45) **Date of Patent: *Aug. 4, 2015**

(54) **MONITORING DEVICE MESH NETWORK SYSTEMS AND METHODS**

(75) Inventors: **Ramiro Trevino**, Mesa, AZ (US); **Lester Anderson**, Verona, NJ (US)

(73) Assignee: **MWA Intelligence, Inc.**, Scottsdale, AZ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 88 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/466,562**

(22) Filed: **May 8, 2012**

(65) **Prior Publication Data**

US 2012/0221720 A1 Aug. 30, 2012

Related U.S. Application Data

(62) Division of application No. 12/022,253, filed on Jan. 30, 2008, now Pat. No. 8,260,896.

(60) Provisional application No. 60/887,935, filed on Feb. 2, 2007.

(51) **Int. Cl.**

G06F 15/173	(2006.01)
G01D 4/00	(2006.01)
H04L 12/26	(2006.01)
H04L 12/24	(2006.01)

(52) **U.S. Cl.**

CPC ***G01D 4/004*** (2013.01); ***H04L 12/2602*** (2013.01); ***H04L 41/12*** (2013.01); ***H04L 43/00*** (2013.01); *H04L 43/065* (2013.01); *H04L 43/0817* (2013.01); *Y02B 90/242* (2013.01); *Y02B 90/245* (2013.01); *Y04S 20/322* (2013.01); *Y04S 20/40* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,077,582	A	12/1991	Kravette et al.
5,184,179	A	2/1993	Tarr et al.
5,333,286	A	7/1994	Weinberger et al.
5,361,265	A	11/1994	Weinberger et al.
5,602,838	A	2/1997	Kartalopoulos
5,603,060	A	2/1997	Weinberger et al.
5,606,551	A	2/1997	Kartalopoulos

(Continued)

FOREIGN PATENT DOCUMENTS

DE	10033316	A1	1/2002
JP	2003102052	A	4/2003

(Continued)

OTHER PUBLICATIONS

International Search Report and Written Opinion dated Mar. 23, 2009, International Application No. PCT/US2008/052658, 13 pgs.

(Continued)

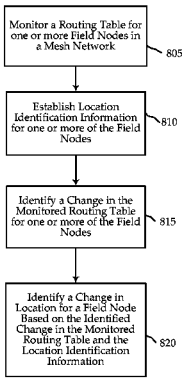
Primary Examiner — Shirley Zhang

(74) *Attorney, Agent, or Firm* — Holland & Hart LLP

(57) **ABSTRACT**

Methods, systems, devices, and software are described for data transmission to and from a monitored device via a mesh network. Monitoring devices report usage, status, location, and other pertinent data via a mesh network, and perhaps other networks as well. Novel data collection, transmission, and aggregation techniques are described. Data transfer may be bi-directional in order to manage and update device status and operation. The monitored device location may be tracked with the reported information.

9 Claims, 11 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

6,009,284	A	12/1999	Weinberger et al.	
6,282,383	B1	8/2001	Weinberger et al.	
6,581,092	B1	6/2003	Motoyama et al.	
6,631,247	B1	10/2003	Motoyama et al.	
6,714,971	B2	3/2004	Motoyama et al.	
6,725,401	B1	4/2004	Lindhorst-Ko	
6,826,267	B2	11/2004	Daum et al.	
6,839,717	B1	1/2005	Motoyama et al.	
6,915,337	B1	7/2005	Motoyama et al.	
6,915,342	B1	7/2005	Motoyama	
6,925,571	B1	8/2005	Motoyama et al.	
7,024,473	B2	4/2006	Parent	
7,043,551	B2	5/2006	Motoyama et al.	
7,047,293	B2	5/2006	Motoyama et al.	
7,050,806	B2	5/2006	Garces et al.	
7,057,555	B2	6/2006	Lewis	
7,069,483	B2	6/2006	Gillies et al.	
7,084,756	B2	8/2006	Stilp	
7,131,070	B1	10/2006	Motoyama et al.	
7,139,820	B1	11/2006	O'Toole, Jr. et al.	
7,149,499	B1	12/2006	Oran et al.	
7,171,670	B2	1/2007	Motoyama et al.	
7,180,852	B1	2/2007	Doverspike et al.	
7,181,619	B2	2/2007	Motoyama et al.	
7,215,658	B2	5/2007	Alastalo et al.	
2002/0126642	A1*	9/2002	Shitama	370/338
2003/0030842	A1*	2/2003	Suyehira	358/1.15
2003/0086368	A1	5/2003	Limaye et al.	
2004/0259555	A1	12/2004	Rappaport et al.	
2005/0253718	A1	11/2005	Droms et al.	
2005/0253722	A1	11/2005	Droms et al.	
2006/0019679	A1	1/2006	Rappaport et al.	
2006/0111796	A1	5/2006	Van Heteren	
2006/0120370	A1	6/2006	Ginchereau et al.	
2006/0122481	A1	6/2006	Sievenpiper et al.	
2006/0146717	A1	7/2006	Conner et al.	
2006/0154642	A1	7/2006	Scannell	
2006/0158329	A1	7/2006	Burkley et al.	
2006/0240848	A1	10/2006	McMahan et al.	
2006/0250980	A1	11/2006	Pereira et al.	
2006/0258375	A1	11/2006	Wilbrink et al.	
2006/0270349	A1	11/2006	Overy et al.	
2007/0001868	A1	1/2007	Boaz	
2007/0099634	A1	5/2007	Chari et al.	
2007/0103303	A1*	5/2007	Shoarinejad	340/572.1
2007/0104123	A1	5/2007	Tomici et al.	
2007/0115951	A1	5/2007	Karaoguz et al.	
2007/0165787	A1	7/2007	Kim et al.	
2007/0183344	A1*	8/2007	Joshi	370/254
2009/0146838	A1*	6/2009	Katz	340/870.02

FOREIGN PATENT DOCUMENTS

JP	2006195811	A	7/2006
WO	WO-9203789	A1	3/1992
WO	WO-2005057834	A2	6/2005

OTHER PUBLICATIONS

International Preliminary Report on Patentability dated Aug. 13, 2009, International Application No. PCT/US2008/052658, 13 pgs.

* cited by examiner

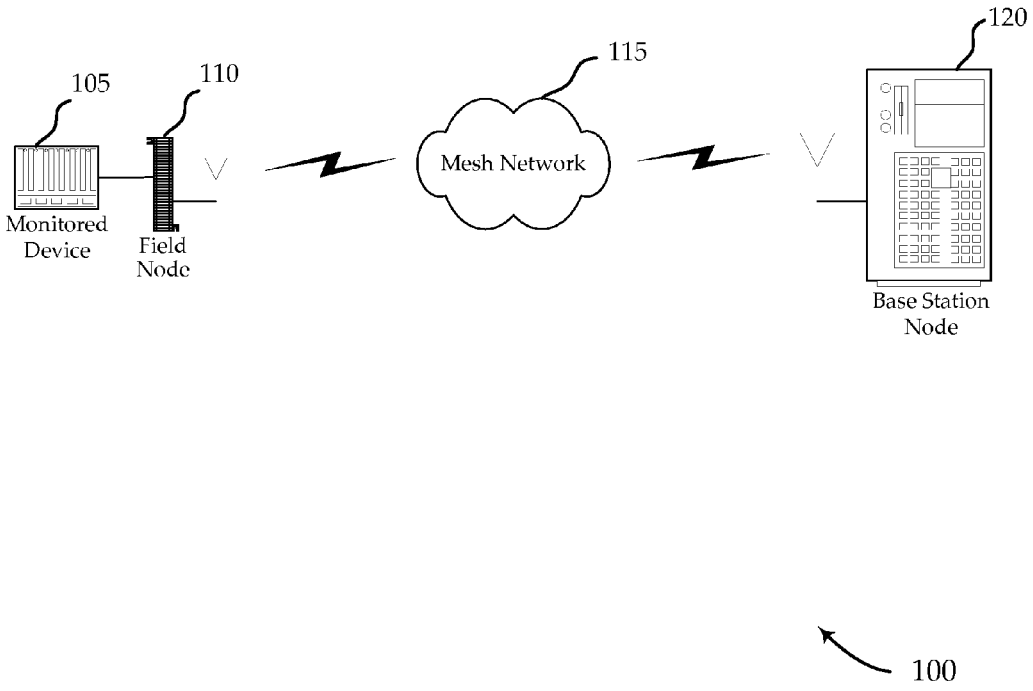

105
110
115
120
Monitored Device
Field Node
Mesh Network
Base Station Node
100

FIG. 1

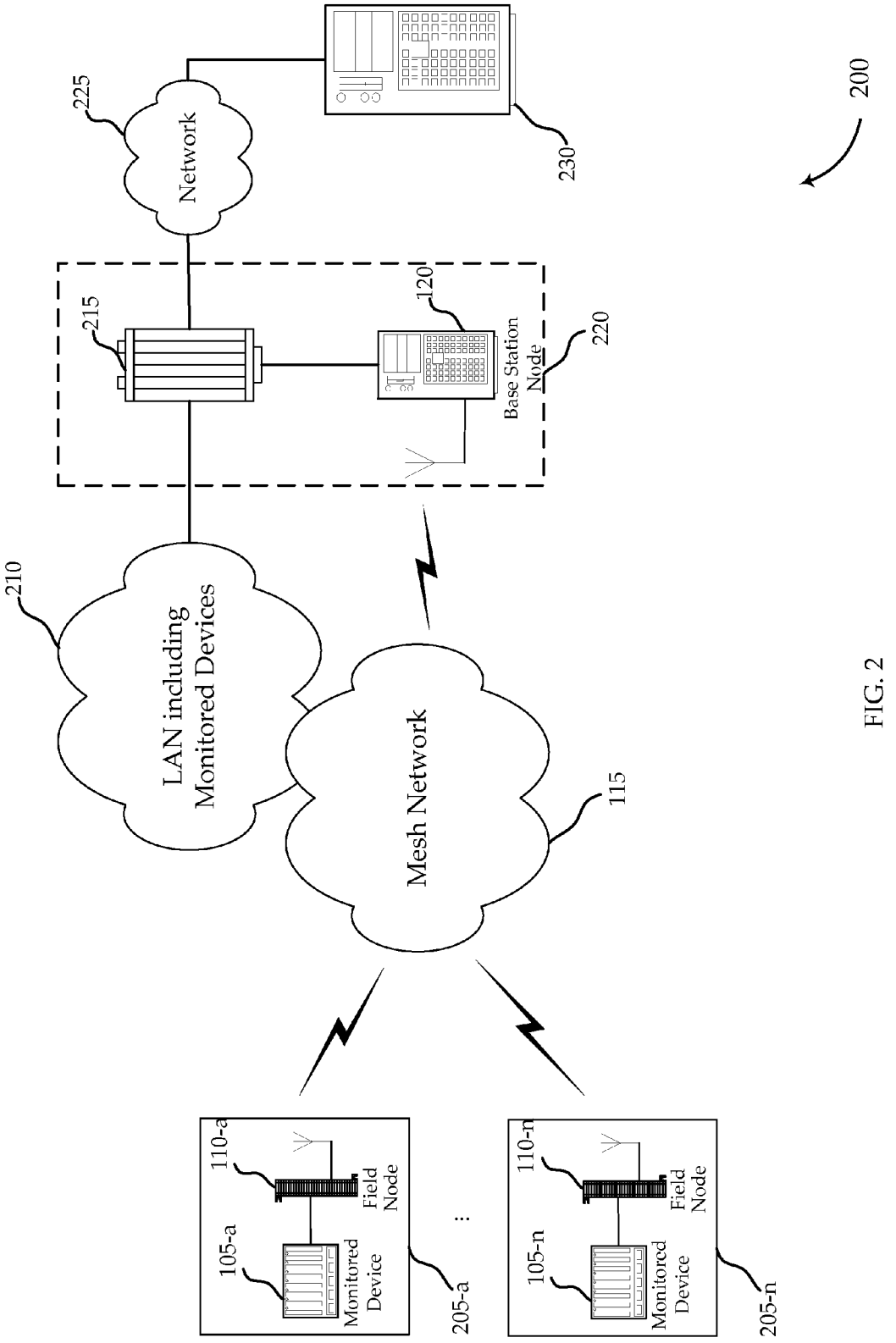

200
225
Network
230
215
120
Base Station Node
220
210
LAN including Monitored Devices
Mesh Network
115
110-a
Field Node
105-a
Monitored Device
205-a
110-n
Field Node
105-n
Monitored Device
205-n

FIG. 2

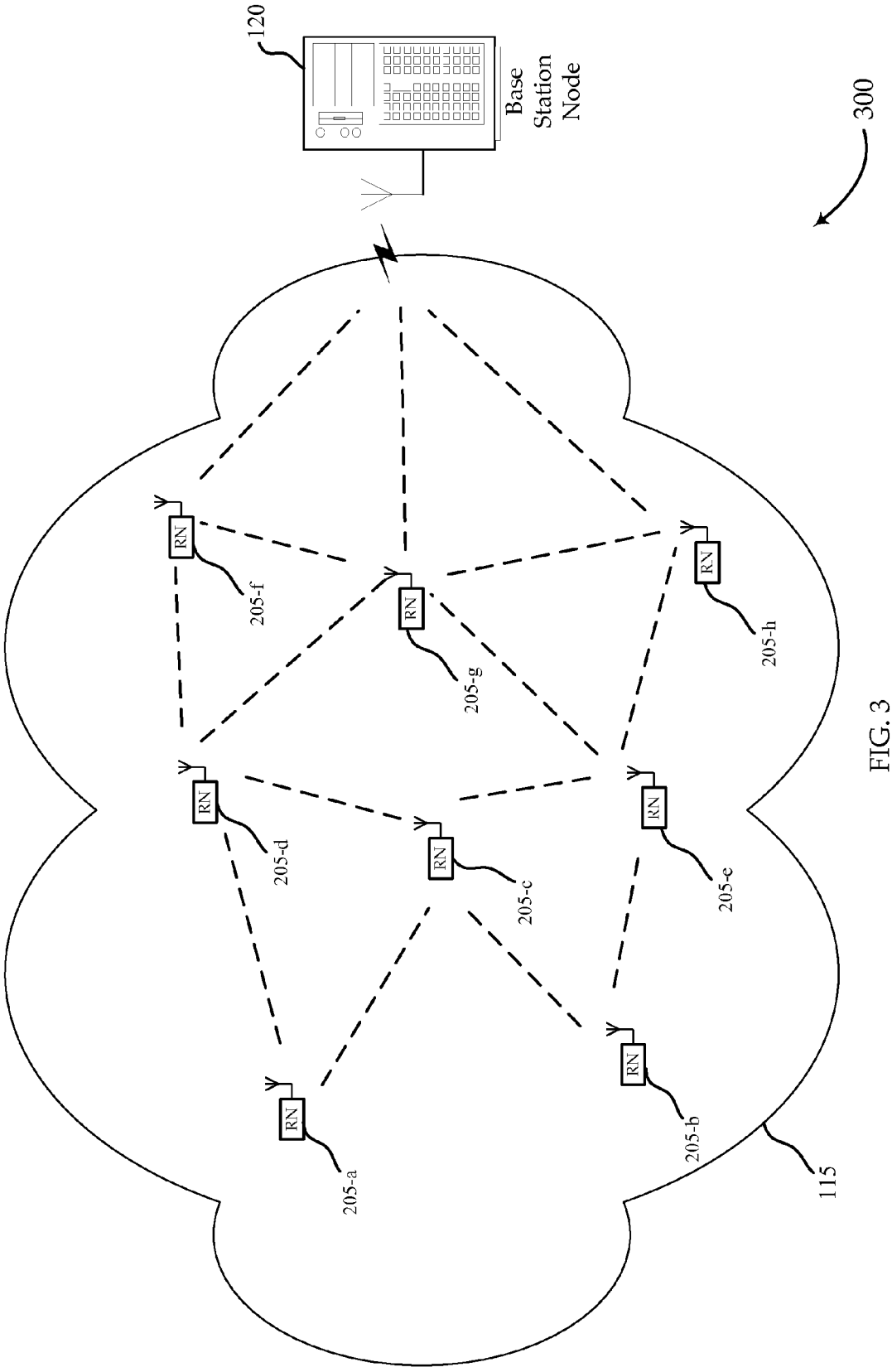

120
Base Station Node
300
RN
205-f
205-g
205-h
205-d
205-c
205-e
205-a
205-b
115

FIG. 3

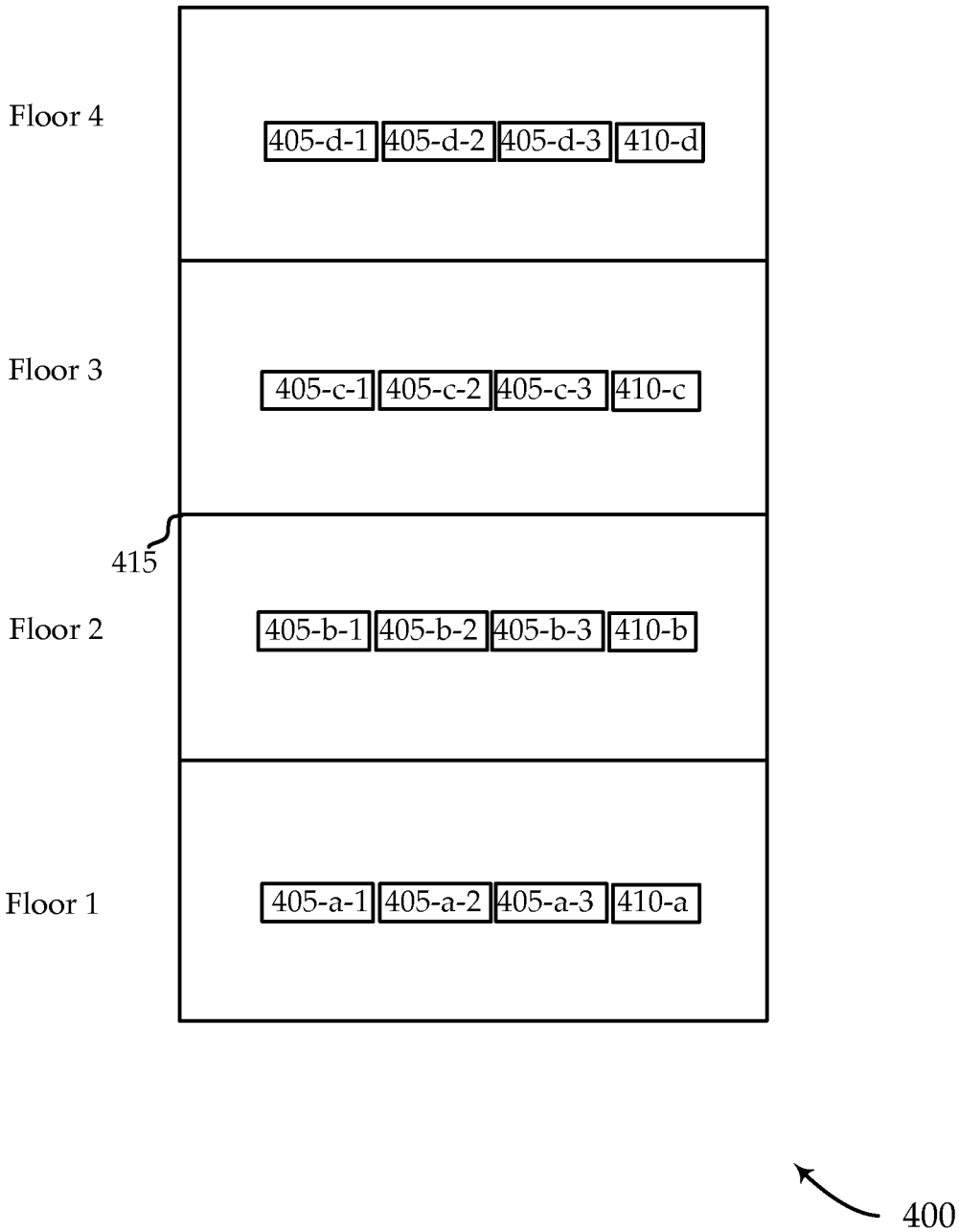

Floor 4
405-d-1
405-d-2
405-d-3
410-d
Floor 3
405-c-1
405-c-2
405-c-3
410-c
415
Floor 2
405-b-1
405-b-2
405-b-3
410-b
Floor 1
405-a-1
405-a-2
405-a-3
410-a
400

FIG. 4A

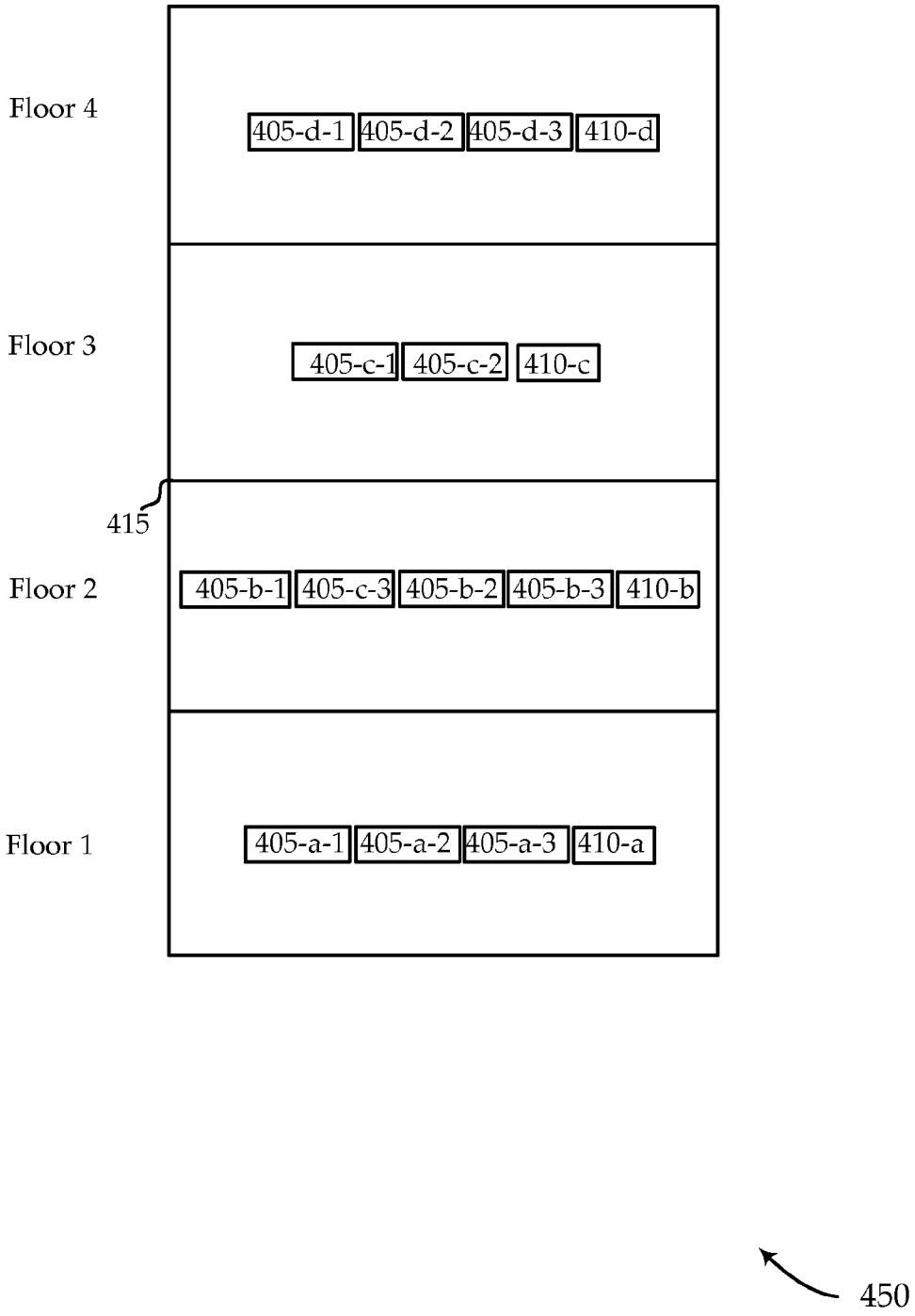

Floor 4
405-d-1
405-d-2
405-d-3
410-d
Floor 3
405-c-1
405-c-2
410-c
415
Floor 2
405-b-1
405-c-3
405-b-2
405-b-3
410-b
Floor 1
405-a-1
405-a-2
405-a-3
410-a
450

FIG. 4B

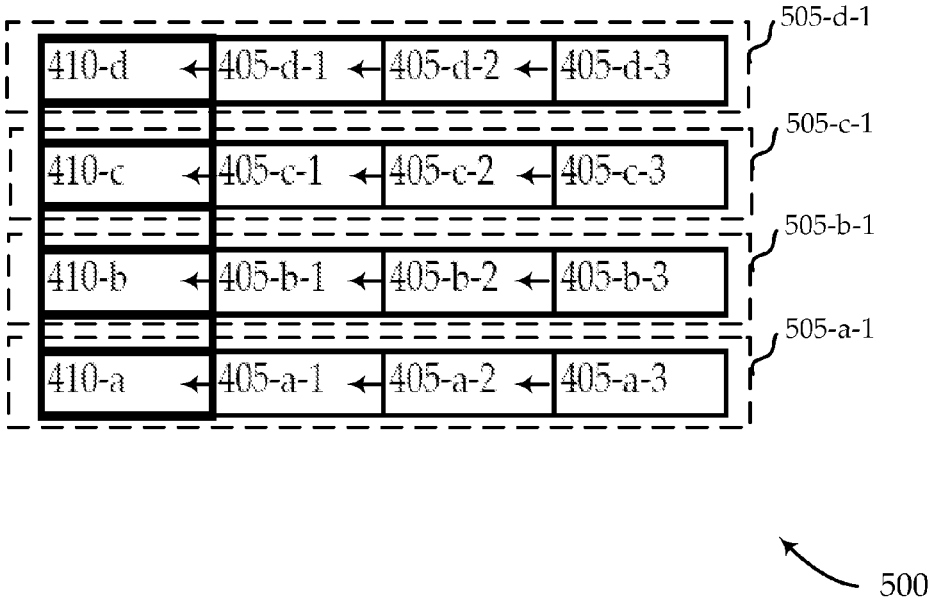

505-d-1
410-d
405-d-1
405-d-2
405-d-3
505-c-1
410-c
405-c-1
405-c-2
405-c-3
505-b-1
410-b
405-b-1
405-b-2
405-b-3
505-a-1
410-a
405-a-1
405-a-2
405-a-3
500

FIG. 5A

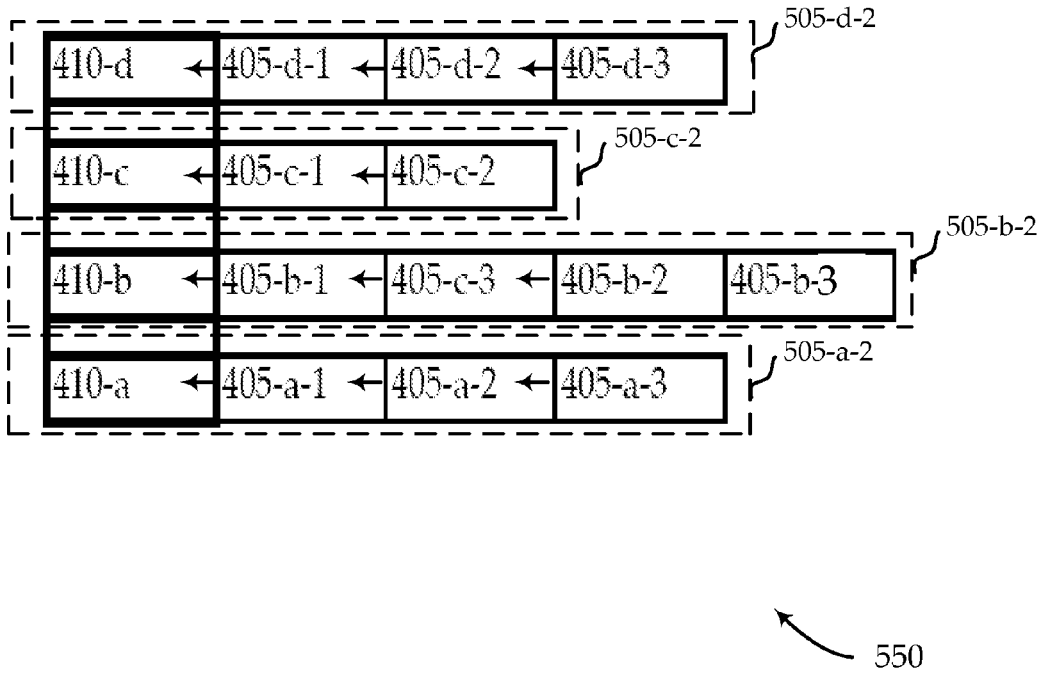

505-d-2
410-d
405-d-1
405-d-2
405-d-3
505-c-2
410-c
405-c-1
405-c-2
505-b-2
410-b
405-b-1
405-c-3
405-b-2
405-b-3
505-a-2
410-a
405-a-1
405-a-2
405-a-3
550

FIG. 5B

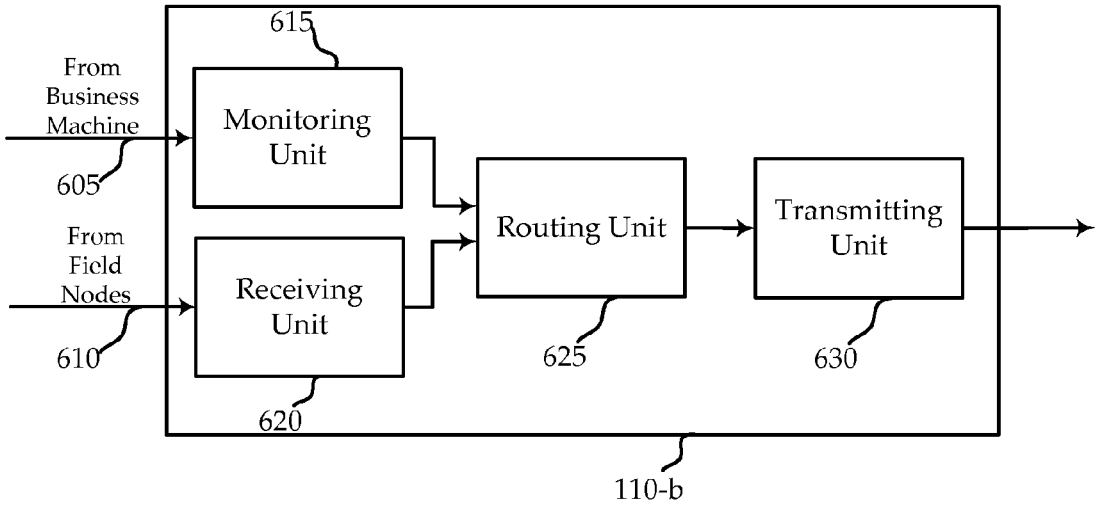

615
From Business Machine
605
Monitoring Unit
From Field Nodes
610
Receiving Unit
620
Routing Unit
625
Transmitting Unit
630
110-b
600

FIG. 6A

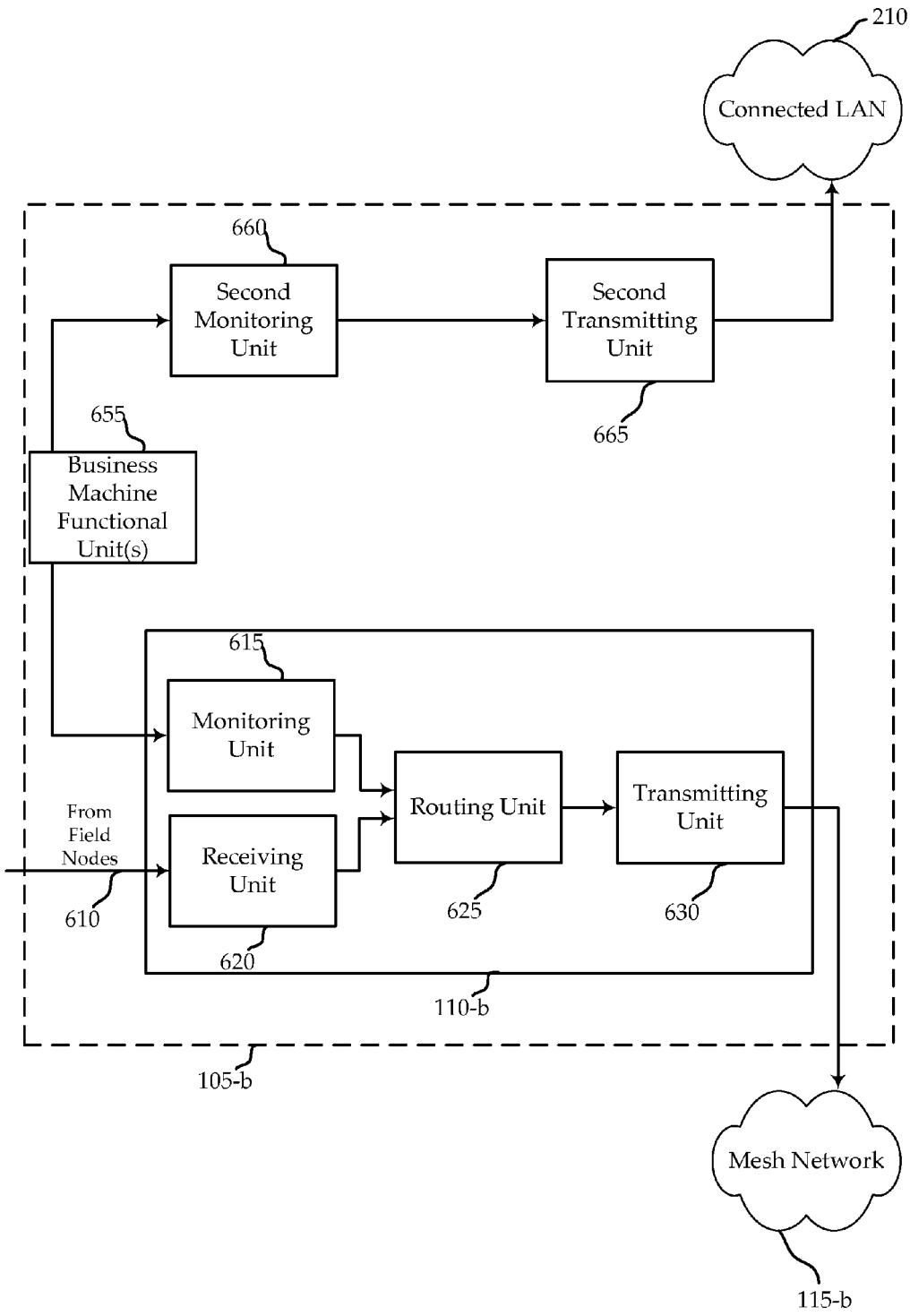

210
Connected LAN
660
Second Monitoring Unit
Second Transmitting Unit
665
655
Business Machine Functional Unit(s)
615
Monitoring Unit
From Field Nodes
Receiving Unit
Routing Unit
Transmitting Unit
610
620
625
630
110-b
105-b
Mesh Network
115-b

FIG. 6B

650

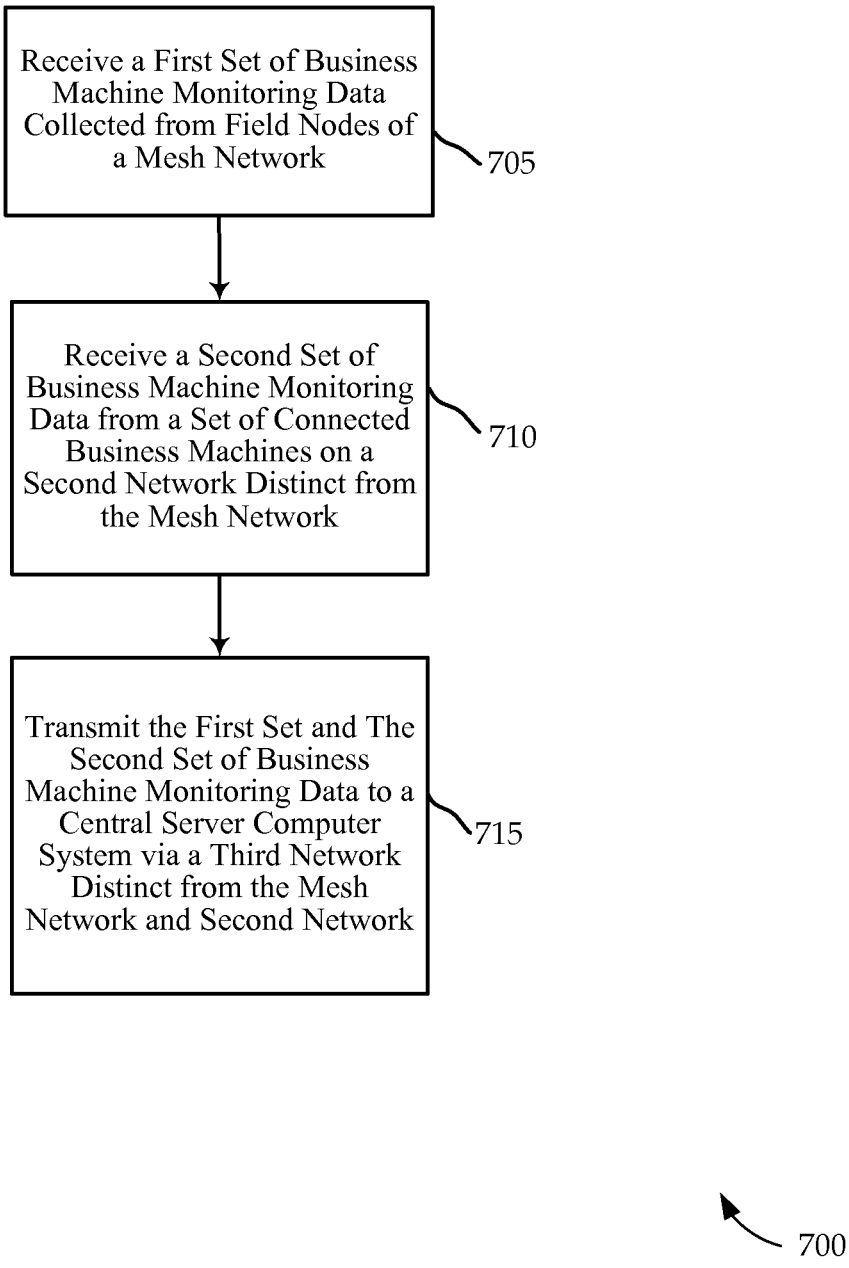

Receive a First Set of Business Machine Monitoring Data Collected from Field Nodes of a Mesh Network
705
Receive a Second Set of Business Machine Monitoring Data from a Set of Connected Business Machines on a Second Network Distinct from the Mesh Network
710
Transmit the First Set and The Second Set of Business Machine Monitoring Data to a Central Server Computer System via a Third Network Distinct from the Mesh Network and Second Network
715
700

FIG. 7

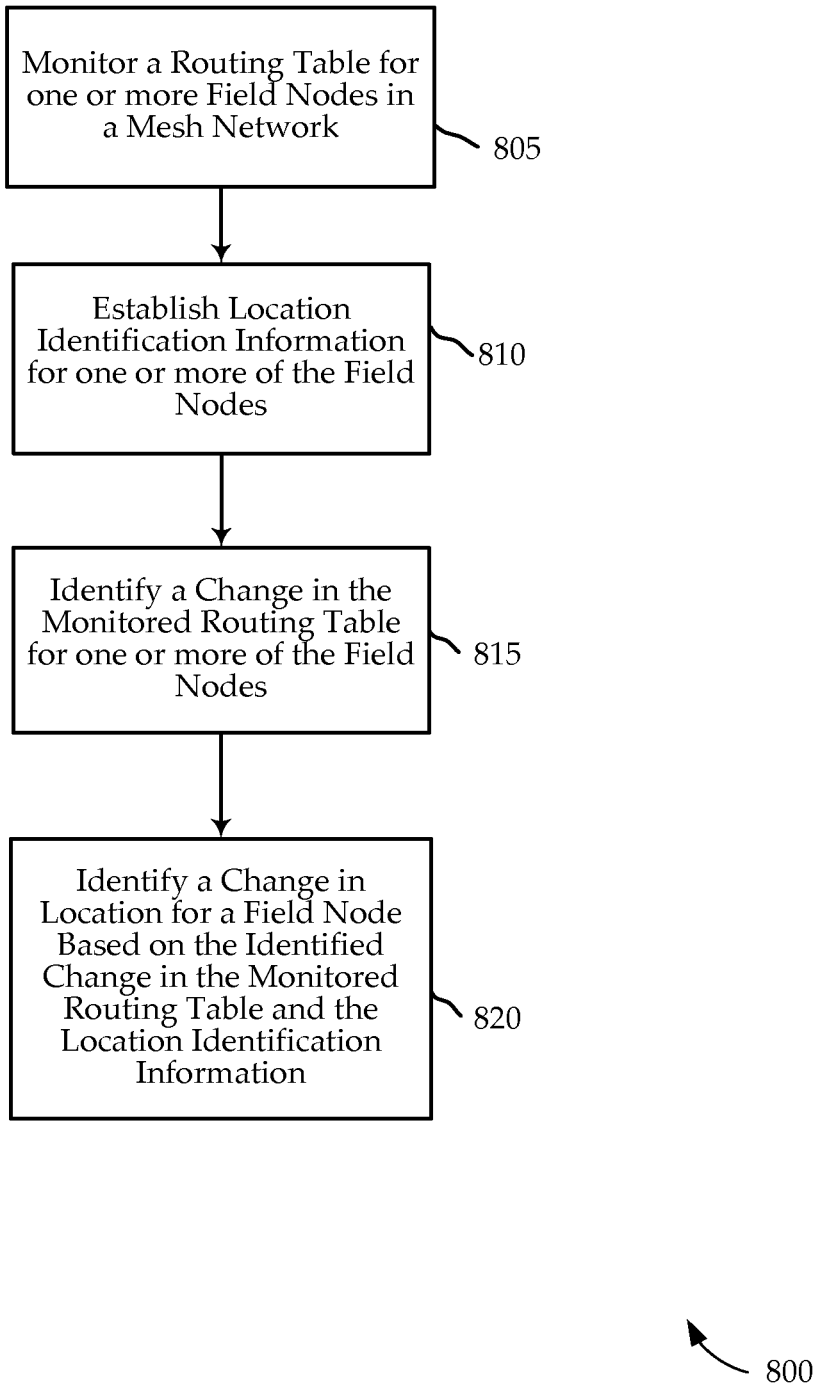

Monitor a Routing Table for one or more Field Nodes in a Mesh Network
805
Establish Location Identification Information for one or more of the Field Nodes
810
Identify a Change in the Monitored Routing Table for one or more of the Field Nodes
815
Identify a Change in Location for a Field Node Based on the Identified Change in the Monitored Routing Table and the Location Identification Information
820
800

FIG. 8

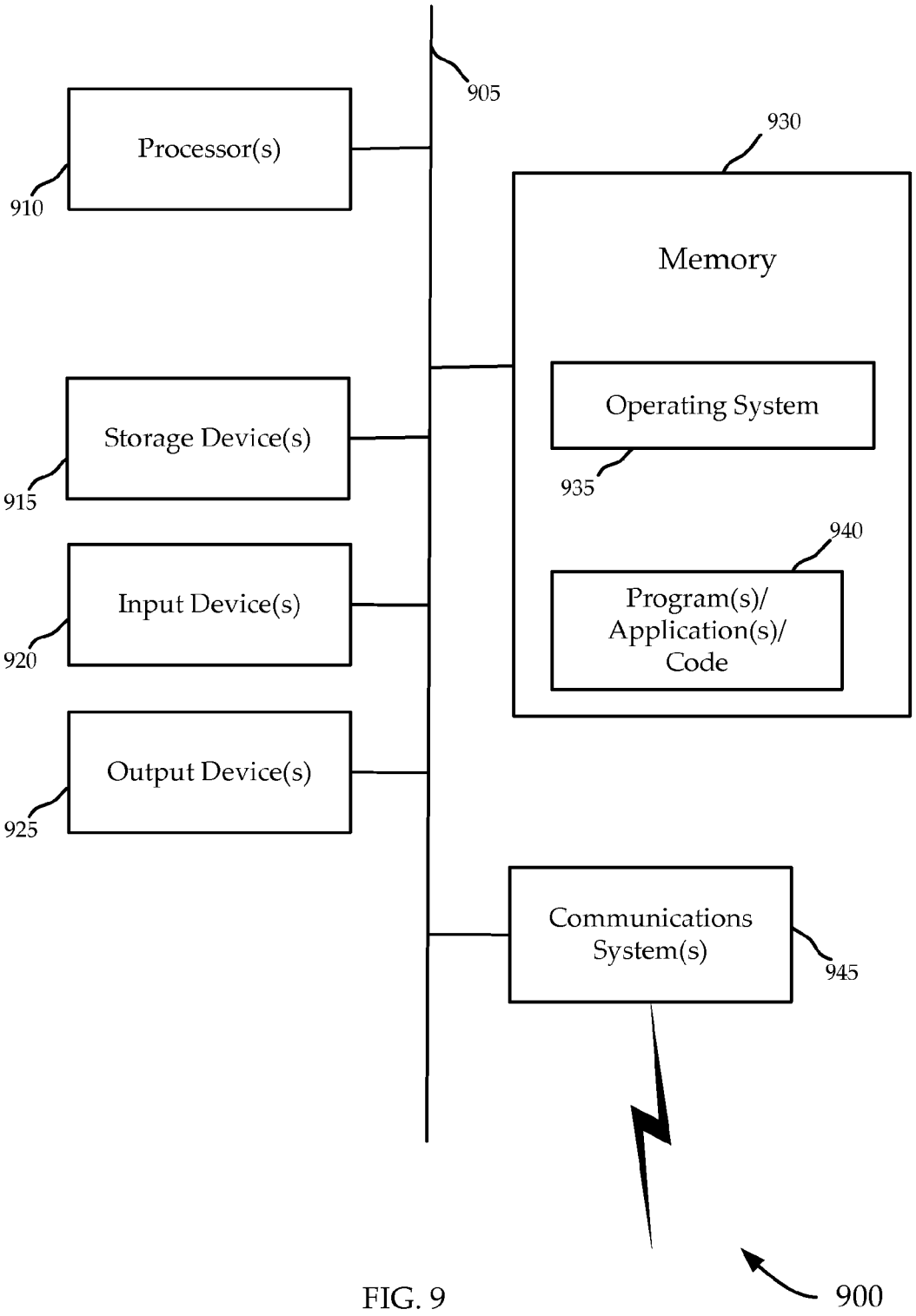

905
Processor(s)
910
930
Memory
Operating System
935
940
Program(s)/
Application(s)/
Code
Storage Device(s)
915
Input Device(s)
920
Output Device(s)
925
Communications
System(s)
945
900

FIG. 9

MONITORING DEVICE MESH NETWORK SYSTEMS AND METHODS

CROSS REFERENCES

This application is a divisional U.S. patent application Ser. No. 12/022,253, filed Jan. 30, 2008 now U.S. Pat. No. 8,260,896, and entitled "MONITORING BUSINESS MACHINES USING A MESH NETWORK ON FIELD NODES", which claims priority from U.S. Provisional Patent Application Ser. No. 60/887,935, filed Feb. 2, 2007, and entitled "METERING DEVICE MESH NETWORK SYSTEMS AND METHODS, the disclosures of which are hereby incorporated by reference in their entirety for all purposes. This application is also related to U.S. patent application Ser. No. 09/929,398, filed Aug. 14, 2001, and entitled "AUTOMATED BUSINESS MACHINE MANAGEMENT", the disclosure of which is also hereby incorporated by reference in its entirety for all purposes.

BACKGROUND

The present invention relates to remote monitoring of a device in general and, in particular to remote monitoring of a device via a mesh network.

Advances in communication networks and electronics, and decreases in the cost of the components therein, have made the remote monitoring of devices become increasingly widespread. Often, devices may be connected to a local area network, and equipped with sensors or other readers which monitor and report status and usage over the local area network. However, this can be limiting because the monitored device may be a mobile device or may be remote from a network connection. Many such monitoring techniques may also be susceptible to a single point of failure. Also, many networks have security features or limited operation hours that may prevent monitoring at certain times.

Although wireless solutions may provide an alternative, they typically require that the communications be transmitted through a service provider (e.g., via pager, cellular, etc.). However, service provider charges may increase the costs in such implementations. In light of the foregoing, it may be desirable to have flexible remote monitoring systems and methods that leverage diverse monitoring networks and are less susceptible to failure.

SUMMARY

Methods, systems, devices, and software are described for multipath data transmission to and from a monitored device via a mesh network. In one embodiment, data collection, transmission, and aggregation are described from one or more devices reporting usage, status, location, and other pertinent data. Data transfer may be bi-directional in order to manage and update device status and operation. The monitored device location may be tracked with the reported information.

In a first set of embodiments, a system for monitoring business machines using a mesh network is described. Field nodes of a mesh network are configured to monitor usage of selected business machines to generate a first set of monitoring data for transmission through the mesh network. A base station node is configured to receive and aggregate monitoring data. A consolidating server is configured to receive an aggregated set of monitoring data, and collect a second set of monitoring data from business machines via a second network distinct from the mesh network. The consolidating server may transmit the first and second sets of monitoring data via a third network to a central server computer system for further processing.

A field node may be integrated into or removably attached to a business machine. A single business machine may be configured to transmit data via both the mesh network and the second network, perhaps allowing the mesh network to be used if the second network becomes unavailable. The consolidating server or base station node may transmit a disable or shut off command to the field node to control operation of the monitored business machine. Business machines may include a copier, fax, printer, and/or or scanner, and the monitoring data may be usage data, status data, or location data. The base station node or consolidating server may identify a change in location (or, more specifically, the new location) of a field node based on a change in a routing table entry associated with the mesh network.

In another set of embodiments, a method of collecting business machine monitoring data is described. A first set of business machine monitoring data collected from field nodes of a mesh network is received via the mesh network, and this data may be aggregated before it is received. A second set of business machine monitoring data is also received, the data collected from a second set of connected business machines on a second network distinct from the mesh network. The first set and the second set of business machine monitoring data are transmitted to a central server computer system via a third network distinct from the mesh network and second network.

In another set of embodiments, a routing table for one or more field nodes in a mesh network is monitored. The routing table may be associated with a single field node, or may be a routing table for a group of field nodes. Location identification information for one or more of the field nodes is established. Thus, certain field nodes may be associated with certain areas (e.g., rooms, floors, or buildings). The location of such field nodes may be known or estimated, and the field nodes may be mobile or affixed.

A change in the monitored routing table is identified for one or more of the field nodes. The change in location for a field node is recognized based on the identified change in the monitored routing table and the location identification information. The change in location may be the identification of a new location or area (e.g., based on an association in a routing table between a field node and a known location), or may simply be an identification of the change. The identified change may result in a re-authentication requirement, additional security commands, or a disable command.

In still another embodiment, an example configuration of a field node in a mesh network for monitoring a business machine is described. The field node includes a first monitoring unit configured to monitor a business machine to generate a set of monitoring data. The field node also includes a routing unit configured to maintain a routing table and use the routing table to identify a destination field node within the mesh network. A first transmitting unit is configured to transmit the set of monitoring data to the destination field node.

The field node may also include a receiving unit to receive other monitoring data from other field nodes of the mesh network, and pass the received monitoring data to the transmitting unit for forwarding. The receiving unit may be configured to receive and execute a disable command initiated by a consolidating server, the disable command generated because of an identified changed location for the field node.

The field node may be attached to or integrated with the monitored business machine. The monitored business machine may include a second monitoring unit, distinct from the first monitoring unit, and configured to monitor the busi-

ness machine to generate and additional set of monitoring data. The monitored business machine may include a second transmitting unit, distinct from the first transmitting unit, and configured to transmit the generated second set of monitoring data over a second network.

BRIEF DESCRIPTION OF THE DRAWINGS

A further understanding of the nature and advantages of the present invention may be realized by reference to the following drawings. In the appended figures, similar components or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label.

FIG. **1** is a block diagram illustrating a system for monitoring a device using a mesh network configured according to various embodiments of the invention.

FIG. **2** is a block diagram illustrating a system for monitoring devices using a mesh network and a second network configured according to various embodiments of the invention.

FIG. **3** is a block diagram illustrating a mesh network monitoring system configured according to various embodiments of the invention.

FIGS. **4**A and **4**B are block diagrams illustrating field nodes communicating via a mesh network in a building according to various embodiments of the invention.

FIGS. **5**A and **5**B are block diagrams illustrating routing tables for a mesh network according to various embodiments of the invention.

FIGS. **6**A and **6**B are block diagrams illustrating field node configurations according to various embodiments of the invention.

FIG. **7** is a method of collecting business machine monitoring data according to various embodiments of the invention.

FIG. **8** is a method of identifying a change in field node location according to various embodiments of the invention.

FIG. **9** is a schematic diagram that illustrates a representative device structure that may be used in various embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Systems, devices, methods, and software are described for multipath data transmission to and from a monitored device via a mesh network. In one embodiment, data collection, transmission, and aggregation are described from one or more monitored devices through a mesh network reporting usage, status, location, and other pertinent data. Data transfer may be bi-directional in order to manage and update device status and operation. The system may be configured to collect information from both connected devices and from devices via the mesh network. The location of a device may be monitored for changes in using routing tables for the mesh network.

This description provides example embodiments only, and is not intended to limit the scope, applicability, or configuration of the invention. Rather, the ensuing description of the embodiments will provide those skilled in the art with an enabling description for implementing embodiments of the invention. Various changes may be made in the function and arrangement of elements without departing from the spirit and scope of the invention.

Thus, various embodiments may omit, substitute, or add various procedures or components as appropriate. For instance, it should be appreciated that in alternative embodiments, the methods may be performed in an order different from that described, and that various steps may be added, omitted, or combined. Also, features described with respect to certain embodiments may be combined in various other embodiments. Different aspects and elements of the embodiments may be combined in a similar manner.

It should also be appreciated that the following systems, methods, and software may individually or collectively be components of a larger system, wherein other procedures may take precedence over or otherwise modify their application. Also, a number of steps may be required before, after, or concurrently with the following embodiments.

Referring first to FIG. **1**, an example of a system **100** configured according to various embodiments is illustrated that includes a monitored device **105**, a field node **110** attached or integrated into the monitored device **105**, a mesh network **115**, and a base station node **120**. The monitored device **105** may be a copier, fax, scanner, computer, or other business machine. Moreover, the monitored device **105** may be any piece of equipment, vehicle, or data interaction unit which generates or communicates information that is used for usage measurement, status, or location reporting (e.g., a movable asset which may be location tracked). The device **105** may, for example, be a gas, electric, or other utility meter, or may be a medical device. It may, for example, be any device which outputs usage and/or peak usage information.

A field node **110** is connected with, integrated into, or otherwise in communication with the monitored device **105**. The field node **110** reads, monitors, checks, or otherwise receives status or usage information from the monitored device **105**. The field node **110** may, for example, acquire data from any data port, sensor or signaling mode of a device **105**, and may be internal or external to the monitored device **105**. The field node **110** wirelessly transmits monitoring data (e.g., status, usage, or location information) to or through the mesh network **115**.

A mesh network **115** is a wireless network in which devices are connected with redundant paths (e.g., more than a single point of failure) between routing nodes of the network. In a mesh network, connection and data paths may be established and updated to allow communications with two or more paths between the field node **110** and the base station node **120**.

A mesh network **115** may be configured automatically, and updated at certain intervals in an ongoing learning mode. The mesh network **115**, therefore, may be configured to determine, establish, and record a most efficient data path for the system transfer of data from the field node **110** to the base station node **120** through the mesh network **115**. Path determination may occur at each monitored device **105**, or the path determination process may be centralized (e.g., made at the base station node **120** or another central server computer, and distributed through the system). Also, alternate paths may be identified for more timely and accurate transmission of the data if one or several of the router nodes becomes inoperative, usage saturated, or otherwise unavailable. Communication may, therefore, be through a prescribed or derived path, and unique identifiers may be collected to identify the path, and passed along from intermediate router nodes to a base station node **120**.

As noted, the system also includes a base station node **120**, in wireless communication with one or more routing nodes of

the mesh network **115**. The base station node **120** receives the usage, status, or location information transmitted by the field node **110** through the mesh network **115**. The base station node **120** may accept, acknowledge reception, and document the reception path of the data. The base station node **120** may aggregate the data. The base station node **120** may pass along all or part of the accumulated and/or aggregated data from the devices to a central computer system, another network or a computer database. Thus, the base station node **120** may aggregate and process the received information, or may simply forward the information (perhaps through the Internet, for example). A reverse path data stream through the mesh network **115** to update a device based on its condition with more current data (e.g., firmware or device operational authority or device identification) may be initiated or passed through the base station node **120**. The reverse path data stream may control certain operations of the device (e.g., shutting down the device based on a change in a routing table entry).

In one embodiment, the system **100** collects status, consumable replenishment, usage (e.g., meter data), office area physical location, and unique node identifier information from a monitored device **105** such as a copier, printer, or other business machine in an office environment. In another embodiment, the system **100** may collect usage data and connection status of a monitored device **105** for an electrical, or heating/cooking gas, or potable water distribution system, where a field node **110** may provide usage metering, peak usage metering and connection (electrical or pressure) status.

In yet another embodiment, the system **100** collects data on a medical device **105**, including the operational status, consumables level and replenishment needs. A field node **110** may report an operational alerting status of health care delivery related devices in a hospital, clinic, doctor's office, or other health care delivery locations. In one embodiment, the system **100** collects location information and usage (mileage) from off-road vehicles, such as farm equipment, or on-road vehicles, such as trucks, buses, or rent-a-cars, where the location information component of that instantaneous usage (mileage) may be used in order to establish a more accurate usage metric. Another embodiment of the system **100** may collect determination of firmware updates of a device **105**, and where needed, transfer data to the devices from the central data repository with appropriate data, commands and authorizations to update the firmware in said device.

Referring next to FIG. **2**, an example of a system **200** is illustrated which includes n monitored devices **105**, which are in communication with a mesh network **115** via field nodes **110**. The system **200** of FIG. **2** illustrates an example embodiment of the system **100** described with reference to FIG. **1**. The field nodes **110** may be attached to, or integrated into, the monitored device **105**. In one embodiment, any subset of the n monitored devices **105** in communication with a mesh network **115** also function as routing nodes **205** of the mesh network **115**. Thus, any subset of the field nodes **110** may also be part of the mesh network **115**. The mesh network **115** provides a communication path for the devices **105** to communicate with the base station node **120**. The system **200** of FIG. **2** also has a local area network **210** that includes other monitored devices. The local area network **210** may be a wired network distinct from the mesh network **115**, but may also have wireless components. A monitored device **105** may be connected with both the local area network **210** and mesh network **115**.

The system **200** of FIG. **2** includes a consolidating server **215**, which is in communication with the base station node **220** and the local area network **210**. The consolidating server **215** may receive and process the usage, status, and location data received for monitored devices **105** via the mesh network **115**. The consolidating server **215** may also collect the usage, status, and location data received for monitored devices from the local area network **210**. Alternatively, the consolidating server **215** may perform relatively little processing, and instead forward essentially raw data through another network **225** (e.g., the Internet, or another network distinct from the mesh network **115** and local area network **210**) to a central server computer system **230** for additional processing.

Although the consolidating server **215** and base station node **120** may be separate devices, they may also be integrated into a single device or set of devices **220**. The consolidating server **215** (or integrated device **220**) may receive and acknowledge data from the mesh network **115** and other types of networks, as well (e.g., in addition to or in lieu of the local area network **210**, data may be received from a cell phone, pager, wi-fi network, or use of one of several protocols including GSM, CDMA, SMS, or GPRS). The consolidating server **215** (or integrated device **220**) may consolidate or separate data received from the various sources into several distribution targets (e.g., different addresses in the network **225** or central server computer system **230**) based on rules of type and content of data elements. As noted, a monitored device **105** may be connected to both the mesh network **115** and the local area network **210** or other network (e.g., for purposes of additional redundancy). Thus, a field node **110** may be configured to transmit monitoring data when the local area network **210** is not operational (e.g., when it not able to transmit monitoring data due to network failure, security limitations, government regulation, or other factors)

In one embodiment, a consolidating server **215** receives monitoring data (e.g., usage, status, or location information from the LAN **210** and/or the mesh network **115**) and transfers that data to an external database (e.g., central server computer system **230**). The central server computer system **230** determines the need for service or a device upgrade. The central computer system **230** may transmit return path data to a monitored device **105** with the information to update the firmware, status, or operational condition of the device **105**. Where physical interaction is needed (e.g., for repair or consumables replenishment), the central computer system **230** may provide location mapping of the monitored devices **105** (integrated across networks) in order to allow a dispatch system to most effectively and efficiently route the sequential visitation of the devices **105**. The consolidating server **215** may also perform any part of upgrade or service determination, mapping, and/or dispatch.

Referring next to FIG. **3**, an example of a system **300** is illustrated which includes a mesh network **115** in communication with a base station node **120**. The system **300** of FIG. **3** illustrates various embodiments of the system **100** described with reference to FIG. **1**. The mesh network **115** of the system **300** of FIG. **3** includes a number of routing nodes **205**. These routing nodes **205** may be the routing node described with reference to FIG. **2**. The routing nodes **205** of FIG. **3** may each be in communication with a subset (or all) of the other routing nodes **205** of the mesh network **115**. Each routing node **205** may also be a field node **110** attached to or integrated into a device **105**. Thus, a field node **110** may have the capability to act in a dual mode, for other devices acting as a routing node **205** to pass along information from other devices to or through the mesh network **115**.

For example, assume that routing node **205**-*a* is also a field node **110** transmitting status, usage, or location data through the mesh network **115** to the base station node **120**. The redundant paths through the mesh network **115** could be a first path through **205**-*d* and **205**-*f* to the base station node **120**, and

a second path through **205**-*c*, **205**-*e*, and **205**-*h* to the base station node **120**. The mesh network **115** may also be configured to identify a best and/or most direct path to a base station, based on predetermined rules (e.g., standard rules or specific rules based on the device **105** or type of information, such as status, usage, or location).

The routing nodes **205** of the mesh network **115** may also transmit location information allowing, for example, the base station node **120**, consolidating server **215**, or other computing device to determine the location of a device **105**, or simply that a device location has changed. The location information may be based on changes in routing table information. For example, when a routing table for a routing node **205** changes, a new routing table entry may indicate proximity to known locations (e.g., new rooms, floors, or buildings) of other routing nodes **205**. As used herein, a "routing table" may include any table or other data structure indicating a path or paths through routing nodes **205** of a mesh network **115**. Various actions may be directed based on changed locations, as access to a monitored device **105** may be shut down or limited, re-authentication may be required, and so on.

By way of example, the time difference of arrival, angle of arrival, and location pattern matching methods may also be used for the mesh network **115** to obtain location information. Location information may be based on triangulation or by special antenna design using routing nodes **205**, or other access points or cellular towers. The location information may, alternatively, be in the form of satellite location information (e.g., GPS), cellular location information, network analysis of location information, location information specific to a building, or other means for location determination. The location information may be GPS coordinates or any other GPS related location information. Additionally, any combination of the above may be used as well, and it is anticipated that location technologies will evolve and the term location information is to be interpreted to include the reception of new forms of location based data.

The location information may be used by a base station node **120** or other computing device, in conjunction with other status or usage information, to identify a sequential service progression through devices **105** requiring service. Thus, the base station node **120** or other computing devices may use the location information, along with other priority information (e.g., service to a medical device at a hospital may be deemed more important than refilling an ink cartridge), to determine service order and priority. The sequential order of service may be determined automatically, or may be provided to a dispatcher. The location information may be utilized to create image data illustrating a map of service stops, and the map may be transmitted to the service technician.

The router nodes **205** (either single purpose router nodes **205** or field nodes **110** serving as a router nodes **205**) may, therefore, pass along status, usage, and location information to a base station node **120**. In that process, the router nodes **205** may add a router node identification code, in order to assist the determination of the physical location of the nodes **205**, both to optimize routing in the mesh network **115** and to identify the location of a device in need of service.

Referring next to FIG. **4**A and FIG. **4**B, block diagrams **400**, **450** are shown illustrating an example of field nodes **405**, **410** communicating via a mesh network in a building according to various embodiments of the invention. These field nodes **405**, **410** may be a field node **110** of FIG. **1** or **2** (and, therefore, may be a router node **205** of FIG. **2** or **3**).

In FIGS. **4**A and **4**B, a number of field nodes **405**, **410** are shown located on different floors of a building **415**. In FIG. **4**A, certain field nodes are shown located on Floor **1** (field nodes **405**-*a*, **410**-*a*), Floor **2** (field nodes **405**-*b*, **410**-*b*), Floor **3** (field nodes **405**-*c*, **410**-*c*), and Floor **4** (field nodes **405**-*d*, **410**-*d*). In this embodiment, a floor includes one type of field node **410** that is known to be located on a given floor, while other field nodes **405** may be mobile and the floor location may be estimated based on routing tables and their relation to the known field node(s) **410**. In FIG. **4**B, one such field node **405**-*c*-**3** is moved from Floor **3** to Floor **2**. Note, again, that the illustrated configurations are for purposes of example only

Turning to FIG. **5**A and FIG. **5**B, a simplified example of various routing tables **500**, **550** are shown. The routing tables **500**, **550** may, for example, be compiled and stored by the base station node **120** or consolidating server **215** to indicate routing paths through various routing nodes. In FIG. **5**A, an illustration of various routing tables shows the routing paths **505** through various field nodes **405**, **410**, and is representative of FIG. **4**A. Each field node may forward an identification code that may be used to compile the routing tables associated with each of a number of known locations. For example, routing path **505**-*d*-**1** illustrates that on Floor **4**, field node **405**-*d*-**3** is routed to field node **405**-*d*-**2**, field node **405**-*d*-**2** is routed to field node **405**-*d*-**1**, and field node **405**-*d*-**1** is routed to field node **410**-*d*. Because location of **410**-*d* is known to be Floor **4**, the floor for the other routing nodes **405**-*d* may be identified as Floor **4**. A similar analysis applies to the other routing paths **505**.

In FIG. **5**B, an illustration of various routing tables again shows the routing paths **505** through various field nodes **405**, **410**, and is representative of FIG. **4**B. As above, each field node may forward an identification code that may be used to compile the routing tables associated with each of a number of known locations. As noted, in FIG. **4**B, field node **405**-*c*-**3** is moved from Floor **3** to Floor **2**. As a result, routing path **505**-*c*-**2** illustrates that on Floor **3**, field node **405**-*c*-**2** is routed to field node **405**-*c*-**1**, and field node **405**-*c*-**1** is routed to field node **410**-*c*. Because location of **410**-*c* is known to be Floor **3**, the floor for the other routing nodes **405**-*c* may be identified as Floor **3**. Because field node **405**-*c*-**3** is no longer routed through field node **410**-*c*, it may be determined that field node **405**-*c*-**3** has been moved.

Similarly, routing path **505**-*b*-**2** illustrates that on Floor **2**, field node **405**-*b*-**3** is routed to field node **405**-*b*-**2**, field node **405**-*b*-**2** is routed to field node **405**-*c*-**3**, field node **405**-*c*-**3** is routed to field node **405**-*b*-**1**, and field node **405**-*b*-**1** is routed to field node **410**-*b*. Because location of **410**-*b* is known to be Floor **2**, the floor for the other routing nodes **405**-*b*, **405**-*c*-**3** may be identified as Floor **2**.

Therefore, the example illustrates how a location change (and perhaps the new location) of a mobile field node **405** may be signaled by changes in a routing table. The location information may be generated by analyzing the changes to a routing path through known or estimated locations of field nodes **410**. While in the foregoing example, floors were used to delineate areas, in other embodiments a known location may be a room, set of rooms, set of floors, building, set of buildings, etc. It is also worth noting that while the illustrated example includes a consolidated routing table, the routing table for a single node may provide similar information.

There are a number of actions that may occur after movement of a field node **405** is recognized by the base station node **120**, consolidating server **215**, or field node **405** itself. For example, certain floors or areas may be prohibited, and movement may cause the monitored device to be shut off or disabled (because of an internal or a remotely generated shut-off or disable command). A change in location may trigger re-authentication requirements. Other security may be triggered

with movement (e.g., an alarm may be triggered causing maintenance or security personnel to re-establish the location of the device). Note that a change in the routing table of a first field node **405** may indicate changes in location of other field nodes (e.g., indicating that a new field node **405** has entered or left a given area (room(s), floor(s) or building(s)).

Turning next to FIG. **6**A, an example configuration **600** of a field node **110**-*b* is shown according to various embodiments of the invention. This may be a field node **110** of FIG. **1** or **2**. In the illustrated embodiment, the field node **110**-*b* includes a monitoring unit **615**, a receiving unit **620**, a routing unit **625**, and a transmitting unit **630**. These units may be implemented, in whole or in part, in hardware. Thus, they may each be made up of one, or more, Application Specific Integrated Circuits (ASICs) adapted to perform a subset of the applicable functions in hardware. Alternatively, the functions may be performed by one or more other processing units (or cores), on one or more integrated circuits. In other embodiments, other types of integrated circuits may be used (e.g., Structured/Platform ASICs, Field Programmable Gate Arrays (FPGAs), and other Semi-Custom ICs), which may be programmed in any manner known in the art. Each may also be implemented, in whole or in part, with instructions embodied in a memory, formatted to be executed by one or more general or application specific processors. The tables described above may be stored in local memory.

In the illustrated embodiment, the field node **110**-*b* may be attached with a monitored device in a removable or more permanent fashion, or may be integrated with the monitored device (e.g., a business machine). The monitoring unit **615** receives **605** monitoring data (e.g., status, usage, or location data) from the monitored device (e.g., in response to specific queries, or perhaps through passive monitoring without specific response from the monitored device). The monitoring unit **615** may acquire the data from any data port, sensor, or signaling mode of the monitored device.

A receiving unit **620** may be configured to receive various types of data **610** from other field nodes. For example, it may receive monitoring data from other field nodes for forwarding. It may also receive commands initiated by, for example, a consolidating server **215** or base station node **120**, which may be formatted to control the functions of the receiving field node (e.g., controlling monitoring, security, routing, disablement functions for the business machine or other monitored device).

A routing unit **625** may maintain a routing table for the transmission of monitoring data within the mesh network. Specific routing paths may be selected by the field node itself, or be received by the field node by another field node, a consolidating server **215** or a base station node **120**. The routing unit **625** may identify a destination field node within the mesh network **115** for transmission of the of monitoring data (either monitored by the field node or received from other field nodes).

A transmitting unit **630** may be configured to modulate, amplify, and upconvert the monitoring data to the destination field node (perhaps for eventual forwarding to a consolidating server **215** or base station node **120**. In other embodiments, it is worth noting that a field node **110**-*b* need not include a receiving unit **620**, and may simply transmit its own monitored data.

Turning next to FIG. **6**B, an example configuration of a system **650** including a monitored device **105**-*b* and field node **110**-*b* coupled thereto is shown according to various embodiments of the invention. In the illustrated embodiment, the field node **110**-*b* described with reference to FIG. **6**A is integrated into monitored device **105**-*a*. As described above with reference to FIG. **6**A, the monitoring unit **615** may receive **605** monitoring data from the business machine functional unit(s) **655** (e.g., copier, scanner, fax, or printer functional units). The transmitting unit **630** of the field node **110** transmits monitored data over a mesh network **115**-*b*.

In the illustrated embodiment, the monitored device **105**-*b* also includes a second monitoring unit **660** and second transmitting unit **665**. These functional units may be in addition to similar units of the field node **110**-*b*. Thus, the second monitoring unit **660** may collect the usage data from the monitored device **105**-*b* differently than the monitoring unit **615** of the field node **110**-*b* (e.g., reading from memory instead of monitoring an output signal). While the same data may be collected in different ways, it is also worth noting that different types of data may be monitored by each unit (e.g., the monitoring device **615** connected with the mesh network **115** may collect and forward location information and may serve as a backup monitoring device, while the second monitoring device **660** may collect usage data). The second transmitting unit **665** may transmit the monitored data via the connected local area network **210**, the connected local area network **210** distinct from the mesh network **115**-*b*. While the illustrated embodiment shows a monitored device **105**-*b* with two distinct communication interfaces and separate monitoring units **615**, **665**, in other embodiments the may be a single interface, network, and/or monitoring unit.

Turning to FIG. **7**, a flowchart is shown illustrating a method **700** of collecting business machine monitoring data according to various embodiments of the invention. The method **700** may, for example, be performed in whole or in part by any combination of the base station node **120**, consolidating node **215**, or the central server computer system **230** of FIG. **1** or **2**.

At block **705**, a first set of business machine monitoring data collected from field nodes of a mesh network is received via a mesh network. The first set of data may be aggregated before reception by an intermediate device (e.g., a base station node) before it is received. At block **710**, a second set of business machine monitoring data from a second set of connected business machines on a second network distinct from the mesh network is received. At block **715**, the first set and the second set of business machine monitoring data are transmitted to a central server computer system via a third network distinct from the mesh network and second network.

Turning next to FIG. **8**, a flowchart is shown illustrating a method **800** of identifying a change in field node location according to various embodiments of the invention. The method **800** may, for example, be performed in whole or in part by any combination of the base station node **120**, consolidating node **215**, or the central server computer system **230** of FIG. **1** or **2**.

At block **805**, a routing table for one or more field nodes in a mesh network is monitored. The routing table may be associated with a single field node, or may be a routing table for a group of field nodes. At block **810**, location identification information for one or more of the field nodes is established. Thus, certain field nodes may be associated with certain areas (e.g., rooms, floors, or buildings). The location of such field nodes may be known or estimated, and the field nodes may be mobile or affixed.

At block **815**, a change in the monitored routing table is identified for one or more of the field nodes. At block **820**, the change in location for a field node is identified based on the identified change in the monitored routing table and the location identification information. The identified change in location may be the identification of a new location (e.g., based on an association in a routing table between a field node with a

known location), or may simply be an identification of change. The identified change may result in a re-authentication requirement, additional security commands, or a disable command.

A device structure **900** that may be used for a monitored device **105**, field node **110**, base station node **120**, consolidating server **215**, routing node **205**, server computer system **230**, or other computing device described herein is illustrated with the schematic diagram of FIG. **9**. This drawing broadly illustrates how individual system elements of each of the aforementioned devices may be implemented, whether in a separated or more integrated manner. The example structure is shown comprised of hardware elements that are electrically coupled via bus **905**, including processor(s) **910** (which may further comprise a DSP or special-purpose processor), storage device(s) **915**, input device(s) **920**, and output device(s) **925**. The storage device(s) **915** may be a computer-readable storage media reader connected to any computer-readable storage medium, the combination comprehensively representing remote, local, fixed, or removable storage devices or storage media for temporarily or more permanently containing computer-readable information. The communications system(s) **945** may be one or more wired, wireless, or other type of interfacing connection that permits data to be exchanged with or received from other devices (e.g., two-way communication and receiving location data). The communications system(s) **945** may permit data to be exchanged with any number of networks.

The structure **900** may also include additional software elements, shown as being currently located within working memory **930**, including an operating system **935** and other code **940**, such as programs or applications designed to implement methods of the invention. It will be apparent to those skilled in the art that substantial variations may be used in accordance with specific requirements. For example, customized hardware might also be used, or particular elements might be implemented in hardware, software (including portable software, such as applets), or both.

It should be noted that the methods, systems, and devices discussed above are intended merely to be examples. It must be stressed that various embodiments may omit, substitute, or add various procedures or components as appropriate. For instance, it should be appreciated that, in alternative embodiments, the methods may be performed in an order different from that described, and that various steps may be added, omitted, or combined. Also, features described with respect to certain embodiments may be combined in various other embodiments. Different aspects and elements of the embodiments may be combined in a similar manner. Also, it should be emphasized that technology evolves and, thus, many of the elements are examples and should not be interpreted to limit the scope of the invention.

Specific details are given in the description to provide a thorough understanding of the embodiments. However, it will be understood by one of ordinary skill in the art that the embodiments may be practiced without these specific details. For example, well-known circuits, processes, algorithms, structures, and techniques have been shown without unnecessary detail in order to avoid obscuring the embodiments.

Also, it is noted that the embodiments may be described as a process which is depicted as a flowchart or block diagram. Although each may describe the operations as a sequential process, many of the operations can be performed in parallel or concurrently. In addition, the order of the operations may be rearranged. A process may have additional steps not included in the figure.

Moreover, as disclosed herein, the term "memory" or "memory unit" may represent one or more devices for storing data, including read-only memory (ROM), random access memory (RAM), magnetic RAM, core memory, magnetic disk storage mediums, optical storage mediums, flash memory devices, or other computer-readable mediums for storing information. The term "computer-readable medium" includes, but is not limited to, portable or fixed storage devices, optical storage devices, wireless channels, a sim card, other smart cards, and various other mediums capable of storing, containing, or carrying instructions or data.

Furthermore, embodiments may be implemented by hardware, software, firmware, middleware, microcode, hardware description languages, or any combination thereof. When implemented in software, firmware, middleware, or microcode, the program code or code segments to perform the necessary tasks may be stored in a computer-readable medium such as a storage medium. Processors may perform the necessary tasks.

Having described several embodiments, it will be recognized by those of skill in the art that various modifications, alternative constructions, and equivalents may be used without departing from the spirit of the invention. For example, the above elements may merely be a component of a larger system, wherein other rules may take precedence over or otherwise modify the application of the invention. Also, a number of steps may be undertaken before, during, or after the above elements are considered. Accordingly, the above description should not be taken as limiting the scope of the invention.

What is claimed is:

1. A system for monitoring business machines using a mesh network, the system comprising:

a plurality of field nodes comprising the mesh network, wherein at least a subset of the plurality of field nodes is each configured to:

monitor usage of a selected one of a first plurality of business machines to generate a first set of monitoring data; and

transmit the first set of monitoring data through other field nodes of the mesh network;

a base station node, in communication with the subset of the plurality of field nodes via the other field nodes; and configure to:

receive the first set of monitoring data transmitted from each of the subset of the plurality of field nodes via the other field nodes; and

aggregate the received first set of monitoring data to generate an aggregated set of monitoring data; and

a consolidating server, in communication with the base station node, and configured to:

receive the aggregated set of monitoring data;

collect a second set of monitoring data from a second plurality of business machines via a second network distinct from the mesh network; and

identify a change in location of a field node of the plurality of field nodes based at least in part on a change in a routing table entry associated with the mesh network.

2. The system of claim **1**, wherein a selected field node of the plurality of field nodes is configured to shut down because of a failure to receive a communication from the consolidating server based at least in part on a change in location of the selected field node causing a change in a routing table entry.

3. The system of claim **1**, wherein the consolidating server is further configured to:

identify a new location of a first field node of the plurality of field nodes based at least in part on a change in a routing table entry associated with the mesh network and a known location of at least a subset of the plurality of field nodes.

4. A method of monitoring a location of a plurality of field nodes comprising a mesh network, the method comprising:

monitoring a routing table for each of at least a subset of the plurality of field nodes in the mesh network;

establishing location identification information for one or more of the subset of field nodes;

identifying a change in the monitored routing table for at least one of the one or more of the subset of field nodes; and

identifying a change in location for a first field node of the plurality of field nodes based at least in part on the identified change in the monitored routing table and the location identification information.

5. The method of claim **4**, wherein identifying the change in location comprises:

identifying a new location for the first field node.

6. The method of claim **5**, wherein the new location comprises a new floor, a new room, or a new building.

7. The method of claim **4**, further comprising:

transmitting a set of data to deactivate the first device based at least in part on the change in location.

8. The method of claim **4**, further comprising:

generating an alert to identify a new location for the first field node based at least in part on the identified change in location.

9. The method of claim **4**, wherein,

the first field node comprises a business machine; and

the first field node does not comprise the at least one of the one or more of the subset of field nodes with the change in the monitored routing table.

* * * * *